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GEOLOGY, ENERGY AND MINERAL RESOURCES ASSESSMENT OF THE SAN AUGUSTIN AREA, NEW MEXICO

BY
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GEOLOGY, ENERGY AND MINERAL RESOURCES ASSESSMENT OF THE SAN AUGUSTIN AREA, NEW MEXICO

by

D. Blair Roberts, Jan Krason, and Jaime A. Rizo

SUMMARY

This report is a preliminary assessment of the Geological, Energy, and Mineral (GEM) Resources of the San Augustin Area (GRA) in Catron County of west-central New Mexico. The area includes the Plains of San Augustin and adjacent mountains to the northwest and southeast. Access to the area is from U.S. Highway 60. State Highway 12 passes through the area, along the northwest edge of the Plains of San Augustin.

There are two Wilderness Study Areas (WSAs) in the San Augustin GRA, with a total of 75,140 acres (303.94 km sq.). Both wilderness areas are mostly covered by mid-Tertiary Datil Volcanics and by younger volcanics.

The only known mineral deposits in the area are sand and gravel (used by the New Mexico Highway Department). There are undeveloped deposits of pumiceous tuff and basaltic scoria. However, the area is located only a few miles northwest from the Black Range tin district, one of the few areas of significant tin deposits in the United States. Although the potential for tin in the San Augustin GRA is only moderate, it is important because the United States has almost no primary production of tin. A recent renewal of exploration activity in this area and recent discovery of anomalous concentrations of tin in geochemical samples has increased the importance of assessing the mineral potential of the San Augustin GRA.

The land classification for resource potential shows the highest favorability for sand and gravel and for scoria or cinders. However, the most important potential resource is the tin, which is classified as moderately favorable. Both Wilderness Study Areas in this GRA are very similar in the GEM classification, and both WSAs are moderately favorable for uranium.

The assessment of this area is at a low level of confidence because of the lack of exploration activity and lack of specifically relevant data. The Tertiary/Quaternary rock cover masks almost the entire area. There are only a few published references on the area.

Since the San Augustin GRA is located in proximity to a very important tin district in which geological environments are similar to those within the WSAs, more detailed geological investigations are highly recommended. The further work should include:

1. Specific determination of the stratigraphic position and sequence of tin-bearing strata, including lithostratigraphic, petrologic, and paleogeographic characteristics,
2. Structural features, besides those usually examined, including particularly fault and fracture systems,
3. Metallic and nonmetallic mineralization areas, their associations, sequence and relationship to various types of alteration-specifically in the Datil Volcanics and within the volcano-sedimentary sequence of the Horse Mountain area,

4. Field investigations should also include measurements of radioactivity associated with uraniferous mineralization,
5. Selective petrologic and geochemical sampling should also be considered. The petrographic examination should determine primary rock type and nature of hydrothermal alteration,
6. Promising rock samples should be chemically analysed for tin, major elements, Nb, Rb, Sr, Ti, F and Mo and classified according to favorability for tin and other associated mineralization.

INTRODUCTION

This report is one of a series prepared for the U.S. Bureau of Land Management (BLM) as part of the program for assessment of known and potential resources in previously designated Wilderness Study Areas (WSAs) in New Mexico. As required by the BLM, preliminary assessments have been made of the potential for Geologic, Energy, and Mineral (GEM) Resources in the subject area. The methodology used in this study was as follows:

1. a search for and assemblage of available unpublished and published information and data on the designated WSAs and the surrounding areas,
2. grouping of the WSAs into Geological Resource Areas (GRAs), taking into consideration the local and regional geological settings and requirements of the BLM reporting format,
3. identification of the geological environments favorable for the occurrence of energy and mineral resources in each GRA,
4. limited field verification in areas selected jointly by BLM representatives and Geoexplorers,
5. reinterpretation of the data base needed as the result of observations in the field,
6. land classification for GEM resource potential in the areas studied, including assessments of favorability and of the level of confidence in each WSA.

The assessments are preliminary, and the BLM has recognized this by designating the program as "Phase One " to be followed with more detailed investigation. The total effort expended by Geoexplorers on this GRA was about 4.0 man-months.

In this report, resources are defined as mineral or fossil fuel deposits amenable to economic development under current or reasonably anticipated conditions. Included are:

1. known reserves (measured, indicated, and inferred)
2. deposits currently known to exist but at this time not recoverable, because of either technological or economic constraints, and
3. deposits not presently known but for which favorable geologic environments can be demonstrated.

This terminology follows that of the U.S. Bureau of Mines and the U.S. Geological Survey (1976; 1980) and the term "resources" includes: reserves, conditional resources, hypothetical resources, and speculative resources.

The San Augustin GRA is located in the southeastern part of Catron County, west-central part of New Mexico. The area is south of U.S. Highway 60 and the principal access is from State Highways 12 and 78, which lead to the southwest from U.S. 60. The San Augustin GRA is located in parts of four different 1:250,000 scale topographic map quadrangles. Most of the area is located in the Clifton and Tularosa quadrangles. Small parts at the north end are in the St. Johns and Socorro quadrangles. There are no towns within this GRA, and except for scattered ranches there is only one settlement, at Horse Springs on State Highway 12. The dominant features of this GRA are the Plains of San Augustin and the adjacent mountainous areas. The two WSAs within this GRA are Horse Mountain and Continental Divide, which are situated on the north and south sides of the relatively flat plains, respectively. Specifically, the two WSAs are coded and named as follows:

NM-020-043	Horse Mountain	5,140 acres	20.79 km sq.
NM-020-044	Continental Divide	70,000 acres	283.15 km sq.
	Total	75,140 acres	303.94 km sq.

Both WSAs are administered by the Socorro BLM District.

PHYSIOGRAPHY

The San Augustin GRA is located at the south end of the Colorado Plateau physiographic province and is near the center of the Datil Volcanic field (Fig. 1). The highest elevation within the area is at Horse Peak (9,550 feet) in the north part of the GRA. Other peaks between 9,000 and 9,500 feet are Pelona Mountain, O Bar O Mountain, and Leura Peak. These peaks are all located south of the Plains of San Augustin, a large down-faulted valley in eastern Catron and western Socorro Counties at an altitude of about 6,800 feet. The valley has no surface drainage outlet, but it has been found to have an effective subsurface drainage to the southwest. According to Blodgett and Titus (1973), about 100,000 acre feet per year of ground water flows out of the San Augustin Plains. The Continental Divide crosses the southern of the two WSAs and the prominent peaks of O Bar O Mountain and Pelona Mountin are on the Divide. South of the Continental Divide the drainage system is toward the east into Alamosa Creek which is discharged into the Rio Grande. The northwestern part of the GRA, including Horse Mountain, is drained internally, onto the valley floor.

The fault bounded valley, the Plains of San Augustin, has many of the characteristics of a typical Basin and Range valley such as those found in much of southern Arizona and southwestern New Mexico. It is reasonable to place the boundary of the Basin and Range province at the northwest edge of the Plains of San Augustin and many workers have done so, although sometimes the entire area of the Datil Volcanics has been placed in the Colorado physiographic province. To the southeast, the relationships are concealed by the volcanic cover in the area of the Datil Volcanics.

During the late Pleistocene, the valley was filled by a lake with a maximum area of 255 square miles (Foreman, et al., 1959), known as Lake San Augustin. Wave-cut scarps resulting from the shorelines of the extinct lake are visible at many places around the edges of the valley at altitudes from 6,900 to 7,000 feet. Some of these shoreline deposits are important as potential sources of sand, as well as being useful in reconstructing the Pleistocene history of the lake.

Two large playa lakes are centered in the southwest and northeast ends of the valley. However, no evaporites have been found in the valley sediments, even though one hole was drilled to 2,000 feet (Sec. 28, T5S-R13W, see figure 2). The lack of evaporites further substantiates that the valley has had an outlet during most of its history.

GEOLOGY

The San Augustin GRA is located in the Datil-Mogollon volcanic area of southwestern part of New Mexico and southeastern Arizona. Most of the area is covered by mid-Tertiary volcanics ranging from rhyolite to basalt. The dominant volcanic centers are mainly andesite and basalt. The structure is complicated by Late Tertiary block faulting, with prominent mountain ranges separated by broad intermontane basins partially filled with alluvium and younger volcanics. The principal regional features of the San Augustin GRA and the geologic setting are shown on fig. 1, modified from Bornhorst and Elston (1978).

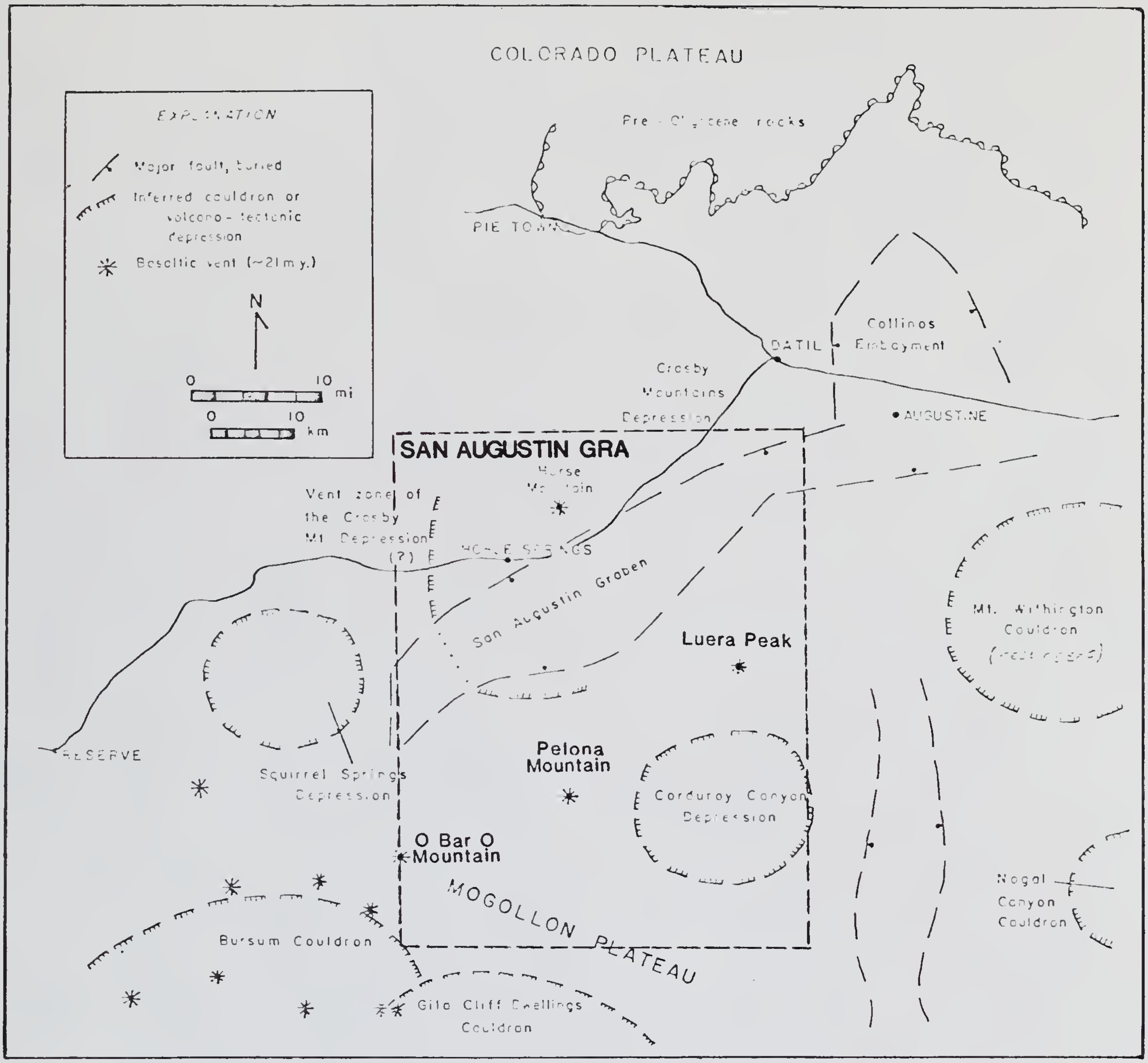


FIG. 1 GENERALIZED STRUCTURAL ELEMENTS OF THE SAN AUGUSTIN GRA AND VICINITY. Modified from Bornhorst and Elston (1978). (San Augustin GEM Resources Area shown by dashed rectangular outline).

Lithostratigraphy - Rock Units

The oldest rocks exposed in the San Augustin GRA are the Permian Yeso Formation (fig. 2 and 3). These rocks are exposed only at several very small outcrops in sections 19 and 20 of T4S-R12W. This is at the northwest edge of the Plains of San Augustin and between State Highway 12 and Horse Mountain. At this location there are small outcrops of Yeso Formation, Glorieta Sandstone, San Andres Limestone and probably the Chinle Formation of Triassic age. These are the only known outcrops of pre-Tertiary rocks in the San Augustin GRA (Stearns, 1962; Willard and Stearns, 1971).

Permian

Yeso Formation

In the San Augustin GRA the Yeso Formation (as well as the other pre-Tertiary rocks) is known only from small outcrops, deep drilling, and from other outcrops outside the area. The Yeso Formation, of Permian (Leonardian) age, is a sequence of light gray to pink crystalline limestone (some porous and oolitic) and gypsum. The exposed thickness is only 200 feet, but the total Yeso thickness should be at least 1,200 feet in this area, based on drilling data from adjacent areas.

Glorieta Sandstone

The Glorieta Sandstone of Leonardian age is light gray to white, partly cross-bedded, lenticular sand with frosted quartz grains. The unit conformably overlies the Yeso Formation and is conformably overlain by the San Andres Limestone. The thickness is about 100 feet.

San Andres Limestone

The San Andres Limestone (Upper Leonardian) in the studied area is light gray to dark gray, partly cherty, silicified, and fossiliferous. Its

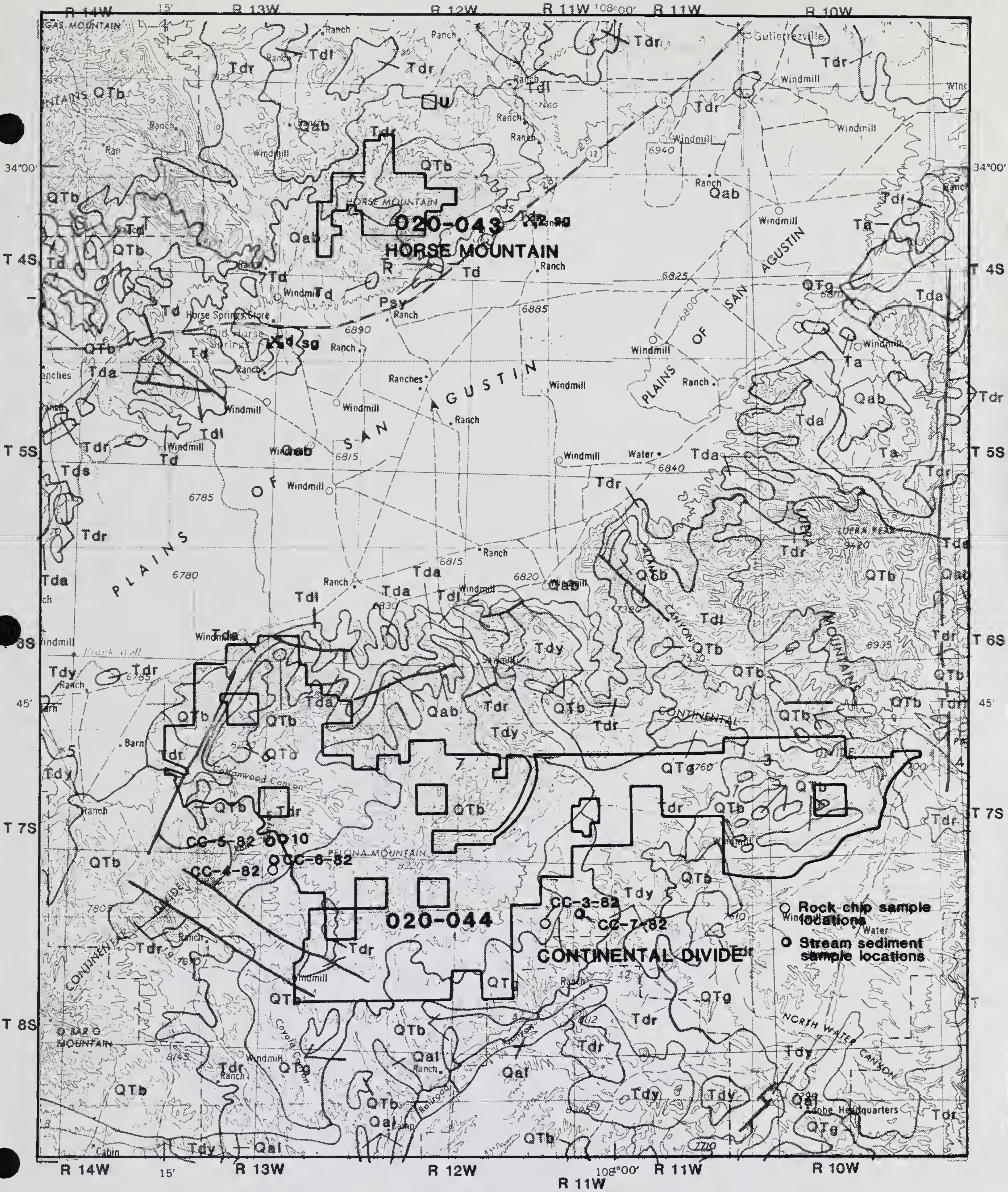


FIG. 2 GEOLOGIC, ENERGY AND MINERAL RESOURCES MAP OF THE SAN AUGUSTIN AREA, NEW MEXICO

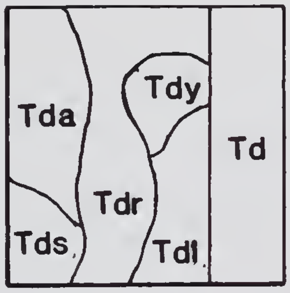
Scale
1 : 250,000
LEGEND: see enclosed

Figure 3. LEGEND
FOR
GEOLOGIC, ENERGY AND MINERAL RESOURCES MAPS

Scale of all maps is 1:250,000 or as otherwise indicated.

LITHOSTRATIGRAPHY

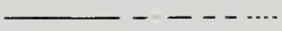
Mainly after C.H. Dane and G.O. Bachman, 1965

QUATERNARY		Qab	ALLUVIUM, bolson deposits, other surficial deposits (mainly in San Augustin plains)
TERTIARY	PLIOCENE	QTg	GILA CONGLOMERATE (Volcanic conglomerate and sandstone, with some interbedded lacustrine units and rhyolitic tuffs)
	MIOCENE	QTb	BASALT and basaltic andesite flows, in upper part interlayered with Gila Conglomerate
	OLIGOCENE		DATIL FORMATION Td – where undivided, comprising a thick sequence that is for the most part divided into several facies which are only in part and locally superimposed stratigraphic units as follows: Tdy – rhyolite flows with phenocrysts of sanidine and smoky quartz Tda – andesite and basaltic andesite flows, and intrusive rocks Tds – clastic rocks of volcanic fragments Tdr – welded and crystal rhyolitic tuffs, flows and breccias Tdl – latite breccias, flow-banded latite, with andesite and rhyolite
	PALEOCENE	Ta	ANDESITE, basalt, and latite flows and pyroclastic rocks
TRIASSIC		TR	TRIASSIC ROCKS (Chinle Formation, undivided, marine shale and fluviatile sandstone)
PERMIAN	LEONARDIAN	Psy	YESO, GLORIETA, and SAN ANDRES FORMATIONS, undivided

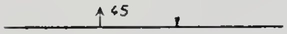
SPECIAL SYMBOLS

OF STRUCTURAL FEATURES

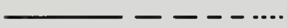
After U.S. Geological Survey



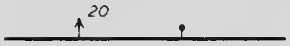
Contact – Dashed where approximately located; short dashed where inferred; dotted where concealed



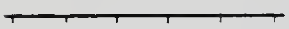
Contact – Showing dip; well exposed at triangle



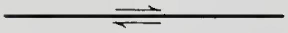
Fault – Dashed where approximately located; short dashed where inferred; dotted where concealed



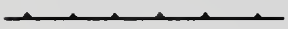
Fault, showing dip – Ball and bar on downthrown side



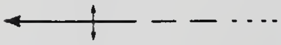
Normal fault – Hachured on downthrown side



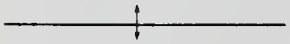
Fault – Showing relative horizontal movement



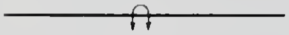
Thrust fault – Sawteeth on upper plate



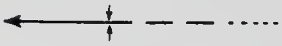
Anticline – Showing direction of plunge; dashed where approximately located; dotted where concealed



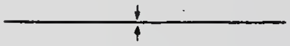
Asymmetric anticline – Short arrow indicates steeper limb



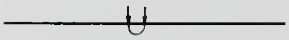
Overturned anticline – Showing direction of dip of limbs



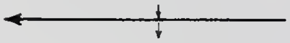
Syncline – Showing direction of plunge; dashed where approximately located; dotted where concealed



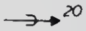
Asymmetric syncline – Short arrow indicates steeper limb



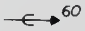
Overturned syncline – Showing direction of dip of limbs



Monocline – Showing direction of plunge of axis

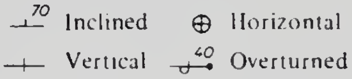


Minor anticline – Showing plunge of axis



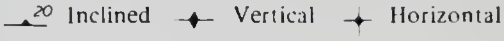
Minor syncline – Showing plunge of axis

Strike and dip of beds – Ball indicates top of beds known from sedimentary structures



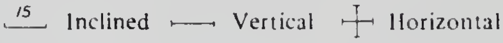
Inclined ⊕ Horizontal
Vertical Overturned

Strike and dip of foliation



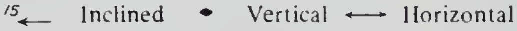
Inclined Vertical Horizontal

Strike and dip of cleavage



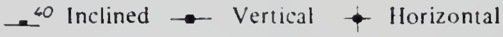
Inclined Vertical Horizontal

Bearing and plunge of lineation



Inclined Vertical Horizontal

Strike and dip of joints



Inclined Vertical Horizontal

Note: planar symbols (strike and dip of beds, foliation or schistosity, and cleavage) may be combined with linear symbols to record data observed at same locality by superimposed symbols at point of observation. Coexisting planar symbols are shown intersecting at point of observation.

SPECIAL SYMBOLS

FOR ENERGY AND MINERAL RESOURCES

KNOWN DEPOSITS AND OCCURRENCES

◯-O Oil field
◌-G Gas field
◯-Os Oil shale

◍-C Coal deposit
⬡-C Coal occurrence

■ - Mineral orebody - as specified with symbol
◨ - Mineral deposit - as specified with symbol
□ - Mineral occurrence - as specified with symbol
▭ - Mineral district (Fig.=inserted map)

EXPLORATION AND/OR MINING ACTIVITY

MINERALS AND COAL

✕ Mineral deposit, mine or prospect with recorded prod.
✕ Prospect or mine with no recorded production
≻— Accessible adit, or tunnel
≻+— Inaccessible adit, or tunnel

◪ Vertical shaft
◩ Inclined shaft
⚒ Active open pit, or quarry
⚒ Inactive open pit, or quarry

⚒ Active gravel or clay (cl) pit
⚒ Inactive gravel or clay (cl) pit
⊕ Exploration hole with data available
⊗ Exploration hole without data
▭ Mining district (Fig.=inserted map)

PETROLEUM

● Oil well
✹ Oil and gas well
☼ Gas well

☼ Show of gas
◑ Show of oil
◑ Show of oil and gas
○ Shut-in well

⊙ CO_2- or He-helium- rich well
⌖ Dry well - abandoned

GROUND WATER

○ Water well of special importance
○ Water well of high yield
○ Flowing water well

◒ Brine
◐ Mineral water

◒ Thermal water
⊛ Radioactive water
▲ Thermal point

ENERGY RESOURCES

O	Oil
G	Gas
Os	Oil shale
Ot	Tar sands
C	Coal
Cb	Lignite (brown coal)
Cp	Peat
U	Uranium
Th	Thorium
Gt	Geothermal

MINERAL RESOURCES

METALS

Al Aluminum
Sb Antimony
As Arsenic
Be Beryllium
Bi Bismuth
Cd Cadmium
Cr Chromium
Cs Cesium
Co Cobalt

Cu Copper
Ga Gallium
Ge Germanium
Au Gold
Fe Iron
Pb Lead
Li Lithium
Mn Manganese
Hg Mercury

Mo Molybdenum
Ni Nickel
Nb Niobium or Columbium
Pt Platinum group
RE Rare earth
Re Rhenium
Sc Scandium
Ag Silver
Te Tellurium

Tl Thallium
Sn Tin
Ti Titanium
W Tungsten
V Vanadium
Zn Zinc
Zr Zirconium and
Hf Hafnium

NONMETALS - INDUSTRIAL MINERALS

ab Abrasives
al Alum
as Asbestos
Ba Barite
be Bentonite
ca Calcite
cl Clay

Construction materials :

- cs Crushed stone
- la Lightweight aggregates, includ.:
    - pm Pumice and volcanic cinders
    - pe Perlite
    - ec Expanded clay, shale, slate
    - vm Vermiculite
- sg Sand and gravel
- cr Cement raw materials
- bs Building stones
- ll Lime

dl Diatomite

Nonmarine and marine evaporites and brines

- pt Potash
- na Salt - mainly halite
- gy Gypsum and anhydrite
- nc Sodium carbonate or sulfate
- bn Boron minerals
- nl Nitrates
- Sr Strontium
- Br Bromine
- cc Calcium chloride
- mg Magnesium compounds

fs Feldspar
F Fluorite (fluorspar)
gs Gem stones
ge Graphite
He Helium
kl Kaolin
ky Kyanite and related minerals
ls Limestone
lm Lithium minerals

mg Magnesian refractories
ml Mica
ph Phosphate
pl Pigment and fillers
qz Quartz crystals
sl Silica sand
S Sulfur
tc Talc
ze Zeolites
hm Humate

SPECIAL GEOLOGICAL FEATURES

POINT OF SPECIAL GEOLOGIC INTEREST

m	Mineral occurrence	s	Structural, bedding, foliation, etc.,	u	Radioactive spring
f	Fossil locality	b	Brecciation, shear zone, etc.,	g	Thermal spring
v	Volcanic phenomenon	y	High yield spring	a	Extensive rock alteration
t	Stratigraphic sequence	p	Spring with mineral water	r	Lithologic type locality

FAVORABILITY POTENTIAL AND LEVEL OF CONFIDENCE FOR MINERAL RESOURCES

FAVORABILITY:

1A - Undefined
1 - Not favorable - combine with either B, C, or D
2 - Low
3 - Moderate
4 - High

combine with either A, B, C, or D

LEVEL OF CONFIDENCE:

A - Insufficient data
B - Indirect evidence
C - Direct evidence
D - Abundant direct and indirect evidence

thickness is 417 feet at the outcrop in sections 19 and 20 of T4S-R12W (Stearns, 1962). At 135 to 190 feet below the top, a 55-foot unit is gray to dark gray, algal to oolitic, with many fossil fragments. At 190 to 222 feet from the top, a 32-foot unit is brownish gray, massive, porous, vuggy, and fetid limestone. Especially these limestones are potental source and reservoir rocks for petroleum.

Triassic

Chinle Formation

The Chinle Formation (Late Triassic) is probably about 1,200 feet thick in the San Augustin GRA, but the exposed Chinle Formation is only about 100 feet of light gray and light brownish red sandstone and conglomerate, with chert and quartz pebbles. This is probably the lower part of the Chinle Formation, roughly equivalent to the Shinarump Conglomerate Member of the Four Corners area.

Tertiary

Pre-Datil Volcanics

These are mostly extrusive volcanics. They are represented by dark greenish to purple andesite and basaltic andesite. Their age is probably Paleocene; they are definitely older than the Datil Volcanics. These older volcanics are important because they are hydrothermally altered and, in southwestern New Mexico, they host significant ore deposits. These older volcanics crop out in the northeast part of the San Augustin GRA, mostly in T5S-R10W (unit Ta, fig. 2). They may also be present at shallow depth under the eastern part of the Continental Divide WSA.

Datil Formation

The Datil Formation is composed of about 3,000 feet of extrusive flows, flow-domes, pumiceous tuffs, tuff-breccias, and associated sediments. The age relations have not been completely worked out, but all the units are believed to be Oligocene (26-40 m.y.). Variety and lithologic composition of the units of the Datil Formation are shown on the lithostratigraphy "legend" of this report. Generally, the composition of the entire sequence ranges from rhyolite to andesitic-basaltic. The associated sediments are mainly sandstone and conglomerate, with some mudstone. These units have been mapped by Willard (1957), Stearns (1962), and by Willard and Stearns (1971), and have also been studied by Goerold (1981) and others. One of the flow units, a white to light gray porphyritic rhyolite containing phenocrysts of sanidine feldspar and smoky quartz, is known to be locally tin bearing in the studied area and in the Taylor Creek tin district at the south edge of the San Augustin GRA (unit Tdy, figure 2). Another unit (Tdr) has some of the same characteristics and may also be tin-bearing. The above-mentioned authors are not in complete agreement on the mapping of these units, but have shown the favorable rhyolite exposed at several places on the flanks of Pelona Mountain.

Younger Volcanics

After the extrusion of the Datil Volcanics, volcanic rocks became more basaltic in composition. These younger flows overlie the Datil rocks and in some places are separated from the Datil by an angular unconformity. The composition ranges from basalt through andesite to latite and some rhyolite. These units have built up the prominent peaks of Horse Mountain, O Bar O Mountain, Pelona Mountain and Luera Peak. At Horse Mountain and Pelona Mountain (see fig. 1), the rocks have been dated as about 21 m.y.B.P. There are some interbedded sedimentary units, gray to buff and brown sandstone and conglomerate, which may be in part correlative with the overlying Gila Conglomerate. The San Augustin graben probably started to form in Miocene time and contains an undetermined thickness of Miocene and Pliocene sediments and volcanics.

Gila Conglomerate

This lithostratigraphic unit is composed of sandstone and conglomerate, made up largely of volcanic fragments, with interbedded tuffs and lacustrine sediments. The Gila Conglomerate is mostly of Pliocene age and is found mainly in the southeast part of the San Augustin GRA. Similar rocks of equivalent age also occur in the subsurface in the San Augustin graben.

Quaternary

The youngest rocks in the San Augustin GRA are Quaternary alluvium and associated bolson deposits in the Plains of San Augustin and minor deposits along the major drainages. Wave-cut shoreline features of ancient Lake San Augustin contain Pleistocene beach sands of possible commercial value. The total thickness of Quaternary sediments in the San Augustin graben is poorly known, but may be about 1,000 feet (Foreman, et al., 1959). The total valley fill in the graben is much greater, probably several thousand feet.

Structural Geology

The dominant feature of the San Augustin GRA is a complex graben valley (see fig. 1) with a downthrow of about 4,000 feet. This is one of the later features in the structural development of this area; it probably started to form at about the same time as the younger volcanics, of Miocene age. These younger volcanics make up the prominent peaks of Horse Mountain, O Bar O Mountain, Pelona Mountain, and Luera Peak, which are composite strato-volcanoes of basaltic to andesitic composition. The younger volcanics overlie the mid-Tertiary Datil volcanics, important host rocks for tin deposits along the south edge of the GRA and potentially within the Wilderness Study Areas. The San Augustin graben is a typical Basin and Range fault-bounded valley except for its orientation, which is NE-SW.

Several subsidence calderas have formed in the volcanic region (see fig. 1). Probably the most important of these in the San Augustin GRA is the Corduroy Canyon Depression, east of Pelona Mountain (fig. 1). The Corduroy Canyon area may contain important undiscovered ore deposits because caldera structures commonly contain hydrothermal ore deposits.

Paleontologic Documentation

The paleontologic record in the San Augustin GRA is essentially derived from two areas: the small outcrops of Permian and Triassic rocks, and the Tertiary to Quaternary sediments of the San Augustin graben. In the first area (Sec. 19 and 20, T4S-R12W), the fossiliferous San Andres Limestone contains an abundant and diverse flora and fauna including algae, brachiopods, gastropods and crinoids. This fossiliferous section may be useful in reconstruction of environments that could have generated petroleum. The overlying Triassic Chinle Formation may also contain fossils that have not been reported.

The Tertiary and Quaternary sediments in the San Augustin graben contain pollen and other organic remains which have been used to interpret the climate during the Quaternary and latest Tertiary in this region (Foreman, et al., 1959). These sediments are not important to an understanding of the GEM Resources of the San Augustin GRA.

Geologic History and Paleogeographic Development

During most of the Precambrian time, the San Augustin GRA was probably part of a stable interior craton. As there are no outcrops of Precambrian rocks in the study area, only sparse information from deep drilling is available. Most of southwestern New Mexico is underlain at depth by granite and granite gneiss (U.S. Geological Survey, 1965; Condie, 1981). A deep well drilled near the northeast corner of the San Augustin GRA (Sec. 29, T3S-R9W) found Precambrian granite gneiss at 12,300 feet (Blodgett and Titus, 1973).

This area was subject to erosion during all the Paleozoic Era, until the Permian Period. The oldest Paleozoic rocks deposited directly on the crystalline basement were probably clastics of the Abo Formation. These rocks do not crop out in the area, but are probably present at depth in the San Augustin graben. The oldest rocks exposed in the San Augustin GRA are the Yeso, Glorieta, and San Andres Formations, all of Leonardian age. This sequence of carbonates and clastics was derived from a source area to the south. The Yeso is a mixed carbonate and clastic sequence and contains some gypsum, which indicates a development of restricted marine circulation which occurred during a part of the Leonardian time. Next, the fluvial or eolian Glorieta Sandstone was deposited in the continental sedimentary environment. Then, the San Andres carbonates indicate shallow marine conditions. The area supported an abundant shallow marine flora and fauna during at least part of San Andres (Upper Leonardian) time.

The area was then emergent until Late Triassic time, when the Chinle clastic sequence was deposited from a southern source area. Jurassic sediments were deposited from the same source area, but were removed by erosion during the Early Cretaceous. Cretaceous marine clastics (Dakota Sandstone and younger) were then deposited, but were then eroded except in low areas.

Volcanism began during the early Tertiary (probably Paleocene) and left a series of andesites and basaltic andesites. Some of these crop out in the San Augustin GRA (Unit Ta). Eruption of the extensive Datil volcanic sequence started in the early Oligocene (about 37 m.y.) and continued until about the end of Oligocene time. During the Miocene, the younger volcanics were emplaced and formed the prominent volcanic peaks that remain today. Also at this time were the beginnings of the extensive block faulting in this area and to the south and east.

In Pliocene time, volcanic conglomerates and sandstones were deposited over much of the area, and later partially eroded. Down-faulting continued in the San Augustin graben, and the resulting valley was mostly filled with sediments and interbedded volcanics. During the Pleistocene, the graben continued to accumulate sediments derived from the adjacent volcanic highlands. Sands and coarser gravels were deposited by the streams leading into the valley. In the late Pleistocene the valley was filled with a large pluvial lake. Relict shoreline features are still visible at many places around the margin of the now extinct lake, and littoral sand deposits are found on some of them. The shoreline features are at altitudes between 6,900 and 7,000 feet and are still horizontal, indicating that there has been little structural movement in this area since the late Pleistocene.

ENERGY AND MINERAL RESOURCES

Known Mineral Deposits with Recorded Production

The only known mineral deposits within the San Augustin GRA are sand and gravel. The sand and gravel deposits have been developed in at least two locations near State Highway 12. The development has been limited by the transportation cost to significant markets. Additional deposits could be developed if needed. Also deposits of pumiceous tuff and volcanic scoria could probably be developed if needed.

Potentially the most important resource in the San Augustin GRA is tin. Although there are no known tin deposits within the GRA, there are significant deposits within a few miles south of the GRA and the tin-bearing volcanic rocks are known to crop out on both of the WSAs in the San Augustin GRA. This will be discussed in the next section.

Sand and Gravel

1. New Mexico Highway Department (?)
   Location: Sec. 34, T4S-R13W
   Map name: Horse Mountain West 7 1/2 minute quadrangle
   No. pits: 3

2. New Mexico Highway Department (?)
   Location: Sec. 12, T4S-R12W
   Map name: Horse Mountain East 7 1/2 minute quadrangle
   No. pits: 1

Other deposits are known and could be developed. For example, Stearns (1962) noted 30 feet of bouldery gravel exposed in cuts north of State Highway 12 in Patterson Canyon (T4S-R14W). These deposits are known, but since they have not been delineated and developed they are discussed in the next section.

Known Prospects and Occurrences with no Recorded Production and Favorability Potential

This part of Catron County has not received much exploration attention, partly because of geographic remoteness and partly because of the thick cover of volcanic rocks and valley-fill sediments. There is one possible uranium occurrence that was identified by interpretation of airborne radiometric data in the National Uranium Resource Evaluation (NURE) program (Texas Instruments Inc., 1979, Figure 2-1 and Table 2-3). This was identified as a "possible uranium prospect" and is in approximately the SW 1/4 of Sec. 21, T3S-R12W in an area shown on fig 2 of this report as felsic Datil volcanic rocks (Tdr). This is a minor anomaly, possibly of little significance, but it does indicate some potential for uranium in felsic volcanics on the north flank of Horse Mountain. The reported anomaly is outside the WSA, but the mapped felsic volcanic unit does extend into the WSA (see fig. 2). The fact that the anomaly was detected in a survey using flight lines three miles apart indicates that undetected anomalies may also exist. One area of uranium in well waters (7 to 17 ppb U) was found in the NURE geochemical sampling of the Tularosa quadrangle (Berry, et al., 1980). In the San Augustin graben, the area shown in figure 2, is probably not very important but does indicate soluble uranium which may have been concentrated into economic deposits. In the NURE evaluation of the Socorro quadrangle (Pierson, et al., 1980) the Baca Formation and underlying Crevasse Canyon Formation were rated as favorable for uranium deposits. However, in the part of the Socorro quadrangle within the San Augustin GRA the depth to the Baca Formation was judged to be more than 1500 meters (4920 feet).

The most important potential mineral resource in the San Augustin GRA is tin. The Black Range tin district, a few miles south of the GRA, has many small tin deposits and prospects in T9S-R11W, and T10S-R12W. The known deposits closest to the San Augustin GRA are along Squaro Creek in Sec. 34, T9S-R11W and Hardcastle Creek (Nugget Gulch) in Sec. 28, T9S-R10W. These are three miles south of the San Augustin GRA, and ten miles south of the Continental Divide WSA. Rhyolitic volcanic units similar to the tin host rocks of the Black Range district are present in the Continental Divide WSA and in the Horse Mountain WSA. The tin production of the Black Range district has been small but it is important because the United States is so critically dependent on imports of tin. The outcrop areas of the favorable rhyolitic volcanics are shown on figure 2 (Tdn and Tdy). Also, in the areas of outcrop of the younger basaltic volcanics, the favorable rhyolitic units are inferred to be present at depth. Underground mining of tin would be feasible in these areas but the basaltic cover makes the discovery of deposits more difficult and the mining more expensive. The distribution of the various volcanic units is discussed further in the section on classifiation of the WSAs with respect to tin potential.

Recently, interest in the San Augustin area for tin (and tungsten) has been increasing. Significant geochemical anomalies in tin have been reported from west of Pelona Mountain, within about six miles of the Continental Divide WSA (Georold, 1981). Also, significant geochemical anomalies in tin have recently been reported from stream sediment sampling in the National Uranium Resource Evaluation of the U.S. Department of Energy (Maassen, 1980). These latter localities are in the St. Johns quadrangle, northwest of Horse Mountain. Stream sediments and rock chips sampled near the continental Divide WSA as part of this study (see fig. 2 and table 1) contain 50 ppm or less tin, but have from 500 to 5000 ppm manganese and 700 to greater than 10,000 ppm titanium.

The San Augustin GRA has potential for oil and gas but does not have the favorability that has led to detailed exploration and development in other areas. This is due in part to the volcanic rocks and valley fill which cover most of the area. There are favorable petroleum source rocks and reservoir rocks in the area, mainly Permian and Cretaceous, but little is known about them because there are very few outcrops of these rocks in or near the area. There has been only one deep test in or near the area. This was the Sun Oil-#1 San Augustin in the SW1/4 of the SW1/4 of Sec. 29, T3S-R9W, a dry hole to the Precambrian with no recorded shows and a total depth of 12,284 feet.

Sand and Gravel deposits have been developed in at least two locations near State Highway 12. The development has been limited by the

Table 1. Geochemical analyses of rock chip and stream sediment samples, San Augustin GRA.

Sample Number	CC-3-82	CC-4-82	CC-5-82	CC-6- 82	CC-7-82	10
Type of Sample	rock chip rhyolite porphyry	rock chip rhyolite porphyry with qtz, feldspar, and alt. biotite	stream sediment	stream sediment	stream sediment	stream sediment
Location	Sec. 1, T8S R12W	Sec. 28, T7S R13W	Sec. 21, T7S R13W	Sec. 28, T7S R13W	Sec. 6, T8S R11W	Sec. 21, T7S 13W
Element						
Fe	2%	1%	2%	3%	2%	10%
Ca	0.05%	0.1%	0.5%	0.5%	0.2%	0.5%
Mg	0.05%	0.1%	0.7%	0.7%	0.5%	2%
Ag	<1	<1	<1	<1	<1	<1
As	<200	<200	<200	<200	<200	<200
B	<10	10	15	15	10	<10
Ba	100	100	300	500	200	200
Be	<2	2	<2	<2	2	<2
Bi	<10	<10	<10	<10	<10	<10
Cd	<50	<50	<50	<50	<50	<50
Co	<5	<5	5	15	<5	20
Cr	<10	<10	50	50	10	200
Cu	10	15	20	15	10	15
Ga	20	20	15	15	15	10
Ge	<20	<20	<20	<20	<20	<20
La	70	20	50	20	50	150
Mn	500	1000	1000	1000	700	5000
Mo	<2	<2	<2	<2	<2	5
Nb	20	<20	<20	<20	<20	50
Ni	<5	<5	15	15	5	100
Pb	50	50	20	15	20	20
Sb	<100	<100	<100	<100	<100	<100
Sc	<10	<10	<10	<10	<10	20
Sn	50	20	<10	<10	<10	20
Sr	<100	<100	200	200	200	<100
Ti	1000	700	3000	3000	1500	>10000
V	<10	10	50	50	20	100
W	<50	<50	<50	<50	<50	<50
Y	50	30	15	20	20	300
Zn	<200	<200	<200	<200	<200	200
Zr	200	100	150	150	150	1000

transportation costs to significant markets. Additional deposits could be developed if needed and also deposits of pumiceous tuff and volcanic scoria or cinders could probably be developed if needed. In addition to the developed deposits of sand and gravel along State Highway 12, other deposits could be developed. For example, Stearns (1962) noted gravel deposits in Patterson Canyon (T4S-R14W) and Alamocito Canyon (T4S-R13W). Stearns did not list the exact locations of the deposits and they are not shown on figure 2 of this report. Stearns also noted sand deposits along the ancient shorelines of the extinct Lake San Augustin.

Mining Claims, Leases, and Material Sites

The only mining claims found in this investigation are a few claims on the east side of Pelona Mountain. However, the area of this GRA has been receiving more exploration within the past few years. The claim records received from the BLM did not show any claims in the area of the San Augustin GRA but there may be claims that could be found by a detailed search of the records of the BLM and of Catron County. Because of the geographic remoteness and the younger basaltic cover, the area has not had much exploration activity until recently. There may be additional new claims that have not yet been recorded with the BLM State Office.

Mineral Deposit Types

Sand and Gravel deposits are mined intermittently from alluvial gravels south of New Horse Springs. Other deposits could be developed if needed. From the Datil Volcanics and the younger volcanics respectively, common varieties of pumiceous tuff and basaltic scoria could probably be developed.

There is a favorable stratigraphic section for oil and gas but the cover of volcanics and valley fill has made exploration difficult, so there have been no oil and gas tests within the San Augustin GRA. One deep dry hole is on the northeast corner of the area (Sun Oil #1 San Augustin in the SW1/4 of the SW1/4 of Sec. 29, T3S-R9W).

The most important consideration in this area is the possibility of tin deposits in felsic volcanics such as the deposits a few miles south of the area. The same felsic volcanics and associated sediments are favorable for uranium deposits.

Mineral Economics

Two factors have deterred exploration and development in this area. These are the geographic remoteness of the area and the Tertiary/Quaternary cover of volcanics and valley-fill. There have not been enough near-surface indications of ore to encourage deep drilling, although there is hydrothermal alteration and the similarity to the Taylor Creek and Squaw Creek tin districts.

The deposits of sand and gravel, pumiceous tuff, and basaltic scoria have been little investigated, because of remoteness from markets.

Strategic and Critical Minerals and Metals

In the San Augustin GRA the potential resources of tin are significant. Although there are no known tin deposits within the two WSAs, there are known deposits within a few miles to the south. These have been discussed earlier in this report. The favorable tin-bearing volcanic units also are present in outcrops on the Continental Divide and Horse Mountain WSAs. The past production from the known tin deposits has been small but the potential is important because the United States is critically dependent on imports for its primary tin supply.

LAND CLASSIFICATION FOR GEM RESOURCES POTENTIAL

The classification scheme used in this report was a two fold system of designation (after BLM, Technical Specifications, Attatchment 9, dated March 24, 1982) to describe:

1. the favorability for the occurrences of GEM Resources, and
2. the level of confidence of the estimate.

The designations used are 1 through 4 and A through D, respectively:

Classification Scheme

1. The geologic environment and the inferred geologic processes do not indicate favorability for accumulation of mineral resources.
2. The geologic environment and the inferred geologic processes indicate low favorability for accumulation of mineral resources.
3. The geologic environment, the inferred geologic processes, and the reported mineral occurrences indicate moderate favorability for accumulation of mineral resources.
4. The geologic environment, the inferred geologic processes, the reported mineral occurrences, and the known mines or deposits indicate high favorability for accumulation of mineral resources.

Level of Confidence Scheme

A. The available data are either insufficient and/or cannot be considered as direct evidence to support or refute the possible existence of mineral resources within the respective area.

B. The available data provide indirect evidence to support or refute the possible existence of mineral resources.

C. The available data provide direct evidence, but are quantitatively minimal to support or refute the possible existence of mineral resources.

D. The available data provide abundant direct and indirect evidence to support or refute the possible existence of mineral resources.

The result is a twofold designation for each commodity (or commodity group) and geographic area discussed. A commodity group may be, for example, all locatable metallics; or the various lacatable metallics may be treated separately such as copper, gold, lead, and silver. A geographic area may be an entire WSA or may be a part of a WSA. The areas outside the WSAs are not classified except as is necessary to add clarity to the designations within the WSAs. An example of the application of the system is as follows: In evaluation of the potential for bituminous coal in any outcrop area of a Precambrian granite batholith, the designation would be 1-C or 1-D. If there are abundant granite outcrops and virtually no possibility of overthrusting or of inaccurate mapping, then the correct designation is 1-D. However, if outcrops are scarce and there is some possibility of inaccurate mapping then the designation 1-C might be appropriate.

Locatable Resources

Metallics

There are no known metallic mineral deposits in the San Augustin GRA, but in the case of tin there are prospects nearby, the same favorable rocks occur in the GRA, and geochemical anomalies occur in the GRA.

Horse Mountain WSA-Tin-

Sub-area 1 (2-B). The favorable rhyolitic flows, tuffs, and breccias are mapped as Tdr and Tdy on figure 2. The areas where these units crop out are classified as moderately favorable for tin.

Sub-area 2 (2-B). This is the southwest part of the WSA where the favorable units are covered by Quaternary alluvium. The favorability is classified as moderate, but the confidence in the assessment is down-graded from C to B because the Quaternary cover precludes any direct evidence of favorability (fig. 4).

Sub-area 3 (2-A). This is the eastern part of the WSA, where the favorable units are covered by younger basalt. The favorable rhyolitic units are inferred to be present in the subsurface but the basaltic cover decreases the probability of discovery and development.

Continental Divide WSA-Tin:

Sub-area 1 (2-B). The favorable rhyolitic flows, tuffs, and breccias are mapped as Tdr and Tdy on figure 2. The areas where these units crop out are classified as moderately favorable for tin (fig. 4).

Sub-area 2 (2-A). In the parts of the WSA where the favorable units are covered by basalt, the favorability for tin is classifed as low. In parts of the east end of the WSA, the basalt has a thin cover of sedimentary rock which is not important enough to change the classification.

Uranium and Thorium

There are no known deposits in the GRA or nearby but the rhyolitic volcanics are known to be favorable.

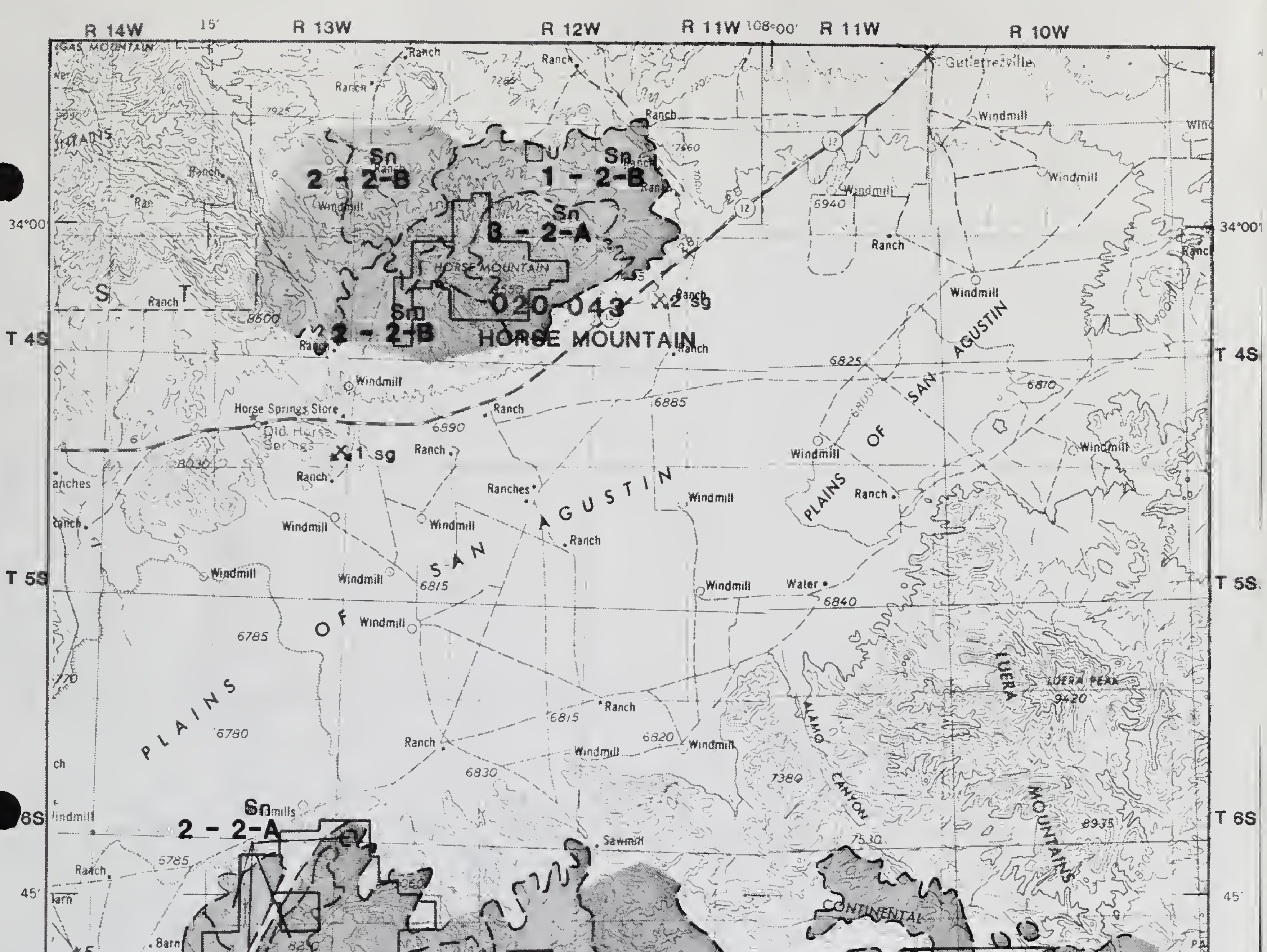


FIG. 4 FAVORABILITY POTENTIAL AND LEVEL OF CONFIDENCE MAP FOR TIN RESOURCES OF THE SAN AUGUSTIN AREA, NEW MEXICO.

Horse Mountain WSA-Uranium

Sub-area 1 (2-B). The outcrop areas of the rhyolitic flows, tuffs, and breccias (Tdr and Tdy on fig. 2) are classified as moderately favorable for uranium.

Sub-area 2 (2-A). The areas where the rhyolitic units are thinly covered by Quaternary alluvium are classified as moderately favorable but the evidence is indirect because of the cover. The area where the rhyolitic units are covered by basaltic volcanic rocks is classified as low favorability because the cover would make prospecting difficult and mining expensive (fig. 5).

Continental Divide WSA-Uranium

Sub-area 1 (2-B). Discussion is the same as in the Horse Mountain WSA.

Sub-area 2 (2-A). The areas where the rhyolitic units are covered by basaltic volcanic rocks are classified as low favorability for the same reasons as noted in the Horse Mountain WSA (fig. 5). In parts of the east and of the Continental Divide WSA, the basalt has a thin cover of sedimentary rock which is not important enough to change the classification.

Nonmetallics

There are no known deposits of locatable nonmetallics in this area. There is abundant smoky quartz and sanidine feldspar in rhyolitic volcanics, but none of gem quality have been reported. However, there has been very little exploration for such deposits because of remoteness and distance to markets.

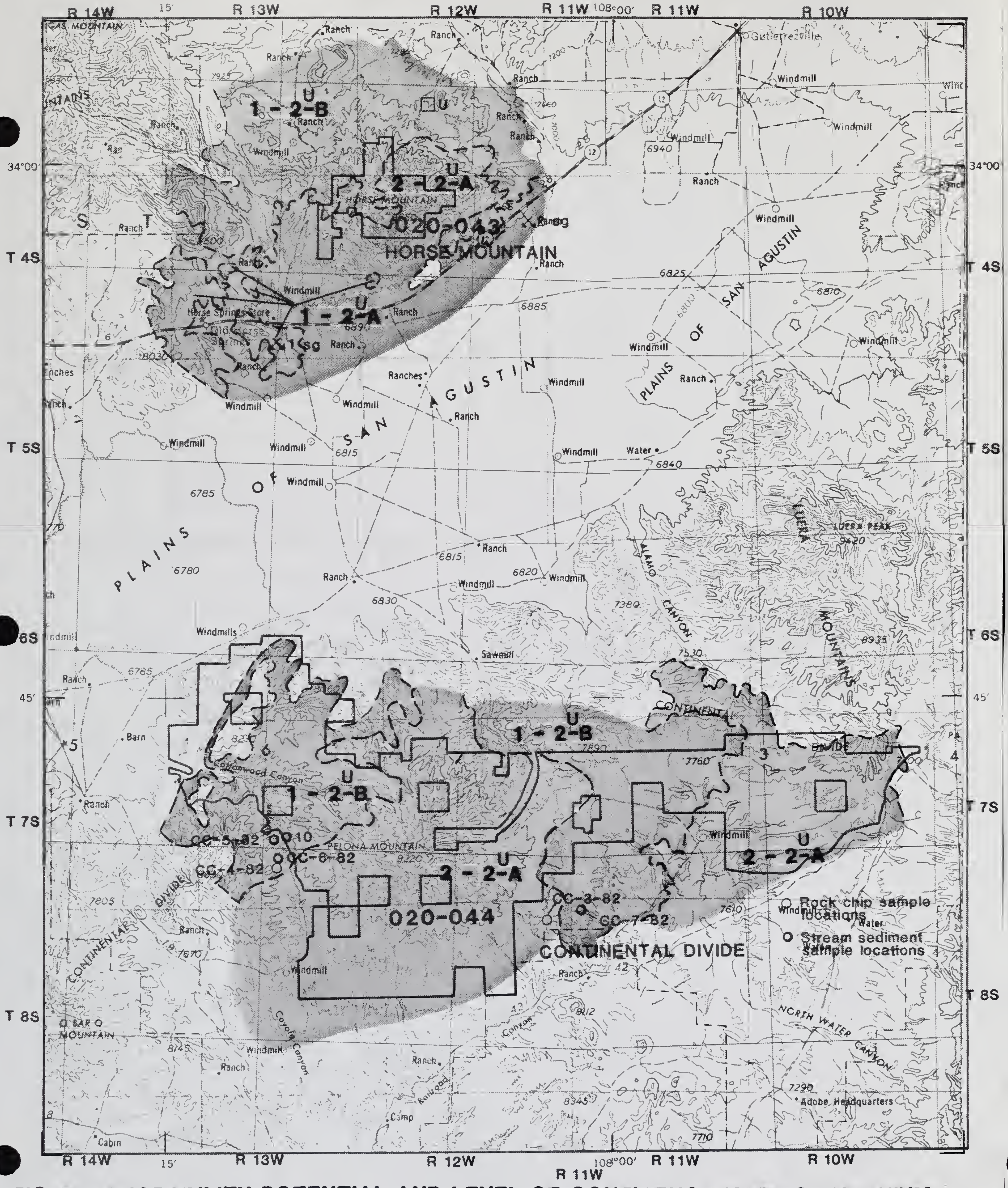


FIG. 5 FAVORABILITY POTENTIAL AND LEVEL OF CONFIDENCE MAP FOR URANIUM RESOURCES OF THE SAN AUGUSTIN AREA, NEW MEXICO.

Leasable Resources

Oil and Gas

The area has petroleum source and reservoir rocks, but little is known about them because of the Tertiary and Quaternary cover. There has been only one deep test, a dry hole.

Horse Mountain WSA

Sub-area 1 (2-C): The Horse Mountain WSA has a low favorability for oil and gas. The small outcrop of Mesozoic and Paleozoic sedimentary rocks in T4S-R12W indicates reservoir rocks and possible source rocks but the structure under the volcanic cover is unknown.

Continental Divide WSA

Sub-area (2-B): The favorability for oil and gas is similar to that of the Horse Mountain WSA but the volcanic cover lowers the confidence in the assessment to 2-B (see sub-area 2-2-B; fig. 6). There are no outcrops of the potentially petroliferous rocks. The confidence level is even less (2-A) in the Plains of San Augustin (sub-area 3).

Geothermal Resources

There are no known geothermal resources in this GRA and no known areas of high heat flow. The area has been little explored, however.

Sodium and potassium Resources

There are no known resources. The only known evaporites are very minor gypsum in the Yeso Formation.

Other Leasable Resources

There are no positive indications of other leasable resources such as oil shale, phosphate, asphalt, or sulfer. There is a slight possibility of

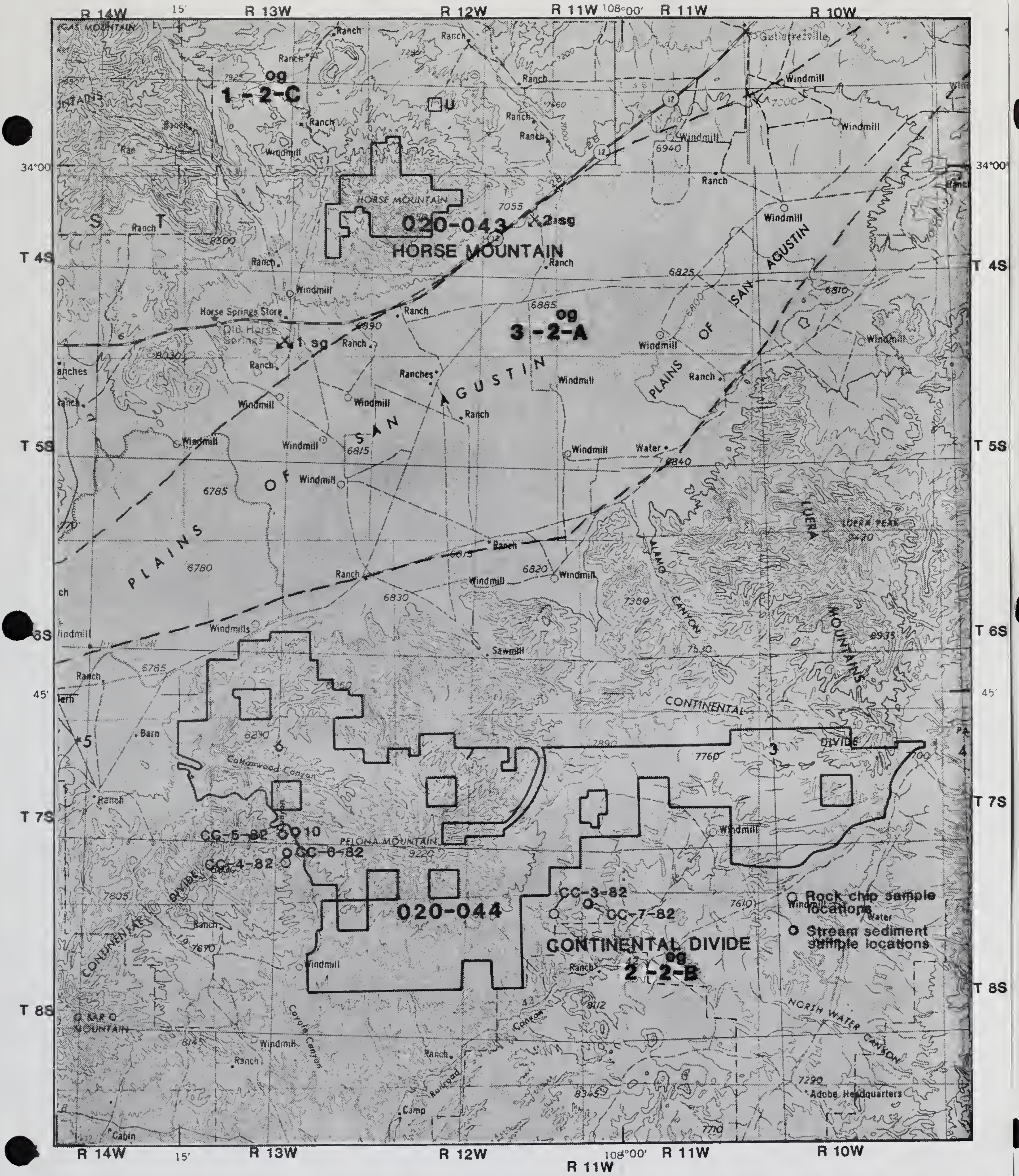


FIG.6 FAVORABILITY POTENTIAL AND LEVEL OF CONFIDENCE MAP FOR OIL AND GAS RESOURCES OF THE SAN AUGUSTIN AREA, NEW MEXICO.

bituminous rock in the San Andres carbonates.

Saleable Resources

Sand and Gravel Resources

There are sand and gravel operations in the San Augustin plains near State Highway 12 that provide material for road building as needed. There are other gravel deposits on stream terraces such at Alamocito Canyon and Paterson Canyon.

Horse Mountain WSA-Sand and Gravel:

Sub-area 1 (4-C). This is the area that has known sand and gravel deposits near State Highway 12. The favorable area is judged to extend a short distance into the southwest part of the Horse Mountain WSA (fig. 7). Similar deposits exist on the south side of the Plains of San Augustin but do not extend into the Continental WSA.

Sub-area 2 (2-B). In the Horse Mountain WSA, the outcrop areas of the volcanic units are classified as having a low favorability for sand and gravel (fig. 7).

Continental Divide WSA-Sand and Gravel:

Sub-area 1 (3-A). The outcrop area of the Gila Conglomerate is classified as moderately favorable for sand and gravel but the assessment is made on insufficient data (fig. 7).

Sub-area 2 (2-B). The outcrop areas of the Tertiary volcanic rocks are classified as low favorability for sand and gravel. These areas may contain small unmapped areas of Quaternary alluvium which would have a higher favorability (fig. 7).

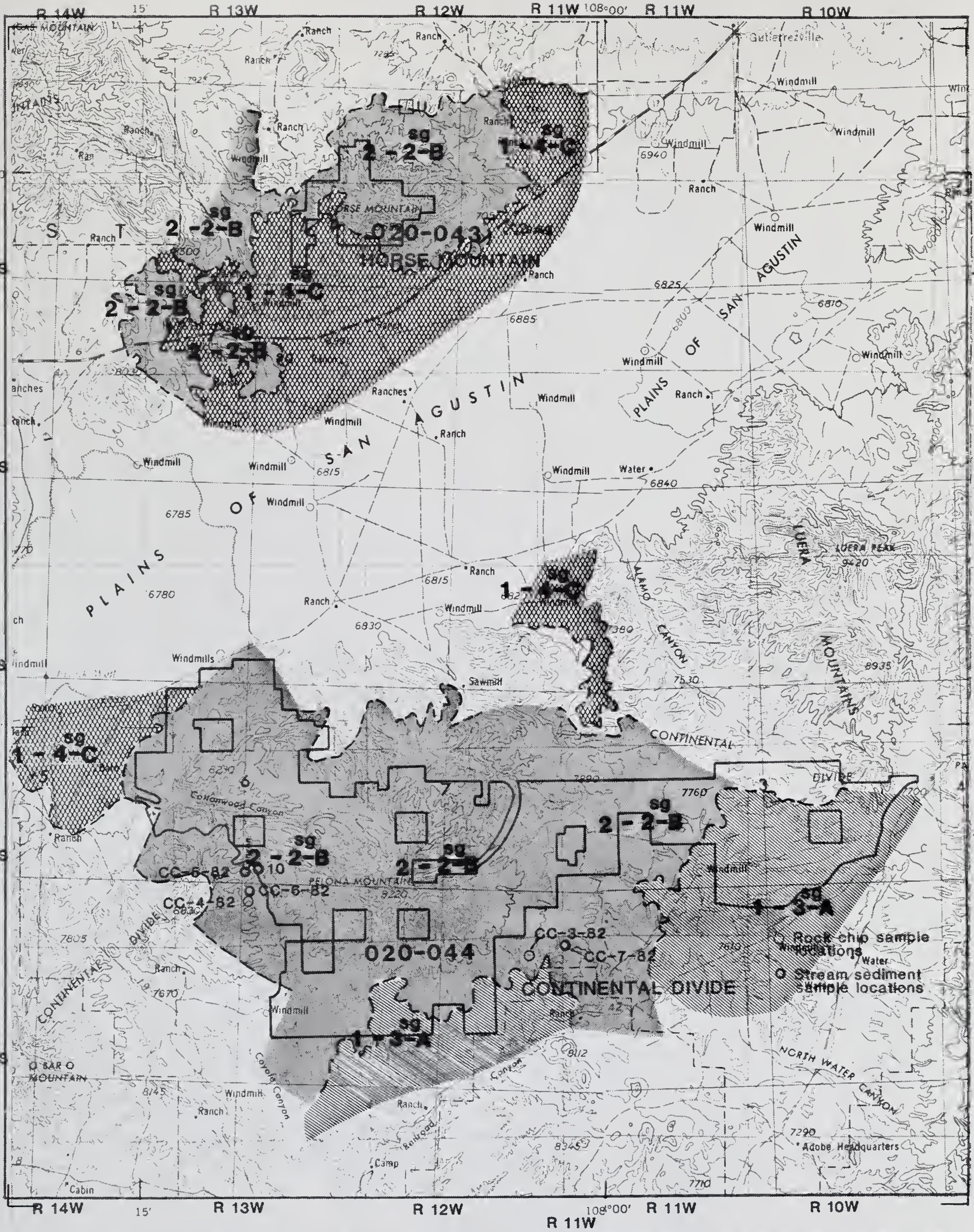


FIG.7 FAVORABILITY POTENTIAL AND LEVEL OF CONFIDENCE MAP FOR SAND AND GRAVEL RESOURCES OF THE SAN AUGUSTIN AREA, NEW MEXICO.

Clay (common varieties) Resources

A high favorability for common varieties of clay is assigned due to the presence of widespread and diverse volcanic flow units, volcaniclastics and lacustrine deposits. The area has received scant attention because of remoteness from markets.

Petrified Wood

There are possibilities of petrified wood in the Chinle formation, in volcaniclastic units and in lacustrine sediments. The area is remote from markets and has not been much explored.

Scoria and Cinders

Vesicular basalt and andesitic basalt is abundant near the tops of flows in the younger volcanics (post-Datil). Common varieties of pumiceous rhyolite are also abundant. Deposits have not been developed because of remoteness from markets.

RECOMMENDATIONS

In this section an evaluation is made of the general level of confidence in the favorability assessments and recommendations are made of the minimum new data needed to improve the level of confidence in the energy and mineral resources assessment. Three general recommendations are listed below and a more detailed recommendation is presented for the first of the three. The detailed recommendation concerns the tin potential of the two WSAs but the same investigation could be directed toward the uranium potential which exists in the same rock units and the same geographic areas.

1. Make detailed measurements and the lithostratigraphic tabulations of sections to estimate thickness of the younger volcanic cover in both WSAs.

2. Study the Corduroy Canyon Depression, a possible favorable cauldron in the Continental Divide WSA, in more detail (see fig. 1 and the section on structural geology).
3. Obtain all possible information on current exploration activity resulting from work by Goerold (1981) and Maassen (1980) and study their data more thoroughly.

The general level of confidence in the assessments made in this report is low. The area has not been much explored, and the field verification phase made as a part this investigation did not allow time to make a sufficient enough geologic examination. The exploration interest in this area has been increasing in the past few years.

Recommendation for Additional Work-San Augustin GRA, Horse Mountain WSA and Continental Divide WSA

The two WSAs within this GRA are both underlain by mid-Tertiary rhyolitic volcanic rocks (units Tdv and Tdy, figure 2). The same volcanic units contain potentially important tin deposits in the Taylor Creek and Squaw Creek districts near the south edge of the GRA and within 10 miles of the south boundary of the Continental Divide WSA. The past production from these deposits and their associated placers has been small but important because tin is a strategic metal and the United States is critically dependent on imports for its primary tin supply. The favorable rhyolitic volcanic units are exposed around the slopes of both Horse Mountain and Pelona Mountain, and in both cases are covered by younger, basaltic, volcanic units in the central parts of the two WSAs (Horse Mountain and Continental Divide). The younger volcanics are not known to contain tin mineralization and in general are unfavorable. The thickness of the younger volanics may be as much as 2000 feet under part of Horse Mountain and 1000 feet under Pelona

Mountain. In addition to the area of exposure of the favorable volcanic rocks, there are areas on the flanks of both mountains that appear to have only a thin cover of the units overlying the favorable rhyolitic units.

Recommended work includes more accurate and detailed mapping of the favorable rhyolite units, geochemical sampling of surface rocks and stream sediments, and construction of cross sections to determine the depth to the favorable units. The available geologic maps in the area are based on mapping by Willard (1957) and by Willard and Stearns (1971). A recent update by Goerold (1981) was mainly a geochemical study and was centered on areas farther north.

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